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FINAL REPORT

of

Research Under Contract NAS 8-31802

March 15, 1976 to March 15, 1977

During the contract period an extensive survey was made of crystal growth literature and related topics. Specific attention was given to those dealing with the effects of transport phenomena on crystal growth. The existing work can be roughly classified into two groups: (i) a large group of empirical observations of effects such as inhomogeneties, temperature oscillations, or growth rate variations which are attributed to fluid convection and (ii) a much smaller group of analyses of convection phenomena in crystal growth systems. Study of this extensive material indicates that although the amount of published work is large the analyses are mostly of an ad hoc type and even they are poorly integrated into experiments, both in their design and in the interpretation of their results. Therefore, and also because convection in crystal growth spans several disciplines that do not normally overlap it was decided to make critical evaluations of each growth technique, viz., closed-tube vapor growth, open-reactor vapor growth, melt growth, and solution growth. Each review is to consist of three parts: (i) a description of the fluid-phase transport processes in the growth technique,

(ii) a critical examination of existing work, and (iii) a listing of suggested topics for further study. In each case related information from other fields that can be helpful will be identified.

The assessment for closed-tube vapor growth was completed and is discussed in the Final Report for Contract NAS 8-31907. The other reviews are not complete but the information derived from the literature is used to make a gross estimate of the relative effects of the space environment on each growth method which will be discussed subsequently. This gives an indication of the growth techniques that will be most affected by reduced gravity.

As an aid to experimenters two papers were prepared (Refs. 1 and 2) in which the types of convective flows that can be expected in reduced-gravity systems were described. The nature of convection is discussed and the relevant dimensionless parameters are delineated. Methods of estimating convection velocities are presented. Typical micro-gravity fields are described and the phenomenon of g-jitter is described. Other driving forces for reduced-gravity convection, such as surface-tension gradients, thermal-volume expansions, Soret effect, are identified and their influence on fluid motions are discussed. The influence of the geometric configuration and boundary conditions on the various types of convection are also indicated.

As was alluded to above it was felt that some preliminary assessment should be made to determine which crystal growth techniques would be most affected by the space environment, i.e., which techniques would be most different in space as compared to Earth conditions. To this end the following matrix was developed.

	Containerless Processing	No forced Flow	Pressure Independent	No Baffles	Normally Unstable	Surface Tension Important
Vapor, closed	−	+	−	−	+ ?	−
Vapor, open	−	−	−	−	+ ?	−
Liquid phase Epitaxy	− ?	− ?	+	+ ?	+	−
Zone Melting	+	+ ?	+	+	+	+
Czochralski	− ?	+ ?	+	−	+	+
Bridgemen	−	+ ?	+	+	−	+
Hydrothermal	−	+	+	−	− ?	−
Solution	− ?	+	+	− ?	+	−

The column headings contain aspects that would be improved, beneficial, or significantly different under micro-gravity conditions. Therefore, if the column heading obtains (indicated by +) the reduced-gravity environment would be interesting and, most likely, beneficial. Note a number of question marks follow the ratings to indicate uncertainties which are of several types. As examples, it may be that it is not certain that the indicated aspect holds such as the "instability" in closed-tube vapor deposition or that the aspect could be modified with a change in configuration or operating conditions as in liquid-phase epitaxy where a forced flow might be induced by rotation.

From the chart it thus appears that zone melting, Czochralski, and Bridgman growth techniques i.e., melt growth would be most affected by the reduced-gravity environment. It, therefore, appears necessary to study melt growth systems in greater detail.

References

1. Ostrach, S.: Convection Phenomena at Reduced Gravity of Importance for Materials Processing, Proc. 2nd European Symp. on Materials Sciences in Space, ESA SP 114, 1976.

2. Ostrach, S.: Convection Phenomena of Importance for Materials Processing in Space (to appear in AIAA Progress Series, 1977).